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PROGRESS IN ENERGY-EFFICIENT COMMERCIAL BUILDINGS AS ASSESSED BY THE DATA BASE AT LBL

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ABSTRACT

The need for actual consumption data to track accurately the improving energy efficiency of buildings is being addressed by the Buildings Energy Data (BED) Group at Lawrence Berkeley Laboratory. We summarize results to date from our Building Energy Use Compilation and Analysis (BECA) studies, which include time trends in the energy consumption of new commercial buildings and the measured savings being attained by the retrofitting of existing commercial buildings. Our analyses are discussed in the context of the commercial buildings presented at this Denver Workshop.

1. INTRODUCTION

In 1981, approximately one-sixth of U.S. resource energy consumption was used by the non-residential buildings sector. For existing buildings, it has been estimated that half the current energy consumption could be saved by careful retrofitting [SERI 1981]. In the case of new construction, commercial buildings can be designed to use one-half or less of the energy of the pre-1975 stock [SERI 1981]. In this article, we wish to discuss how much progress has been made in the past few years towards energy-efficient commercial buildings, with particular emphasis placed on the buildings presented at this workshop.

The analysis of energy usage data to assess progress in the energy efficiency of buildings is being conducted by the Buildings Energy Data (BED) Group at LBL. Metered values of energy consumption are necessary to determine the performance of new buildings and the savings due to retrofits. Good cost data are needed to assess the cost-effectiveness of conservation measures. In the past there has not been a systematic tracking of measured data in order to determine what progress has been made towards the goal of energy-efficient buildings. The BED Group is concentrating its efforts in that direction, establishing a series of data bases that deal with new and existing commercial and residential buildings, appliances and equipment, and the validation of computational tools for estimating energy usage. These data bases provide the factual data needed for load forecasting, policy and program design, and the evaluation of conservation efforts in the buildings sector.

Basic information about each commercial building presented at the Denver Workshop was summarized in the "presenter fact sheets" submitted prior to the beginning of these sessions by the participants. We used this information to separate the buildings into three categories: new commercial buildings with actual performance data, new commercial buildings with design data only, and commercial building retrofits. The summary data for each category are listed in Tables I, II, and III. Our discussions in this paper about progress in both new and existing commercial buildings center around the buildings reported at this workshop.

2. THE BECA DATA BASES

Millions of existing buildings have now been retrofitted and a significant number of new buildings designed and built to save energy compared to conventional construction. Good quality, measured data on actual building energy performances, actual energy savings, and costs of achieving low-energy performance or retrofit savings are necessary to assess the progress that the U.S. is making towards more energy-efficient buildings.

The need for compiling actual building energy performance and cost data, critically analyzing it, and periodically publishing the results is being addressed by the Buildings Energy Data Group at Lawrence Berkeley Laboratory. We have initiated the five-part BECA (Building Energy Use Compilation and Analysis) series which consists of the following:

- o BECA-A analyzes new residential buildings;
- o BECA-B concentrates on residential retrofits;
- o BECA-C covers progress in new and existing commercial buildings;
- o BECA-D deals with energy-efficient appliances;
- o BECA-V assesses the accuracy of building energy computer programs.

In the following sections, we introduce results from the BECA-C data base to discuss time trends in the energy performance of new commercial buildings and the level of success of recent retrofits in the commercial sector. The discussion incorporates the individual buildings presented at this conference.

3. TRENDS IN NEW COMMERCIAL BUILDINGS

In this section we present energy data for office buildings, which have been examined more thoroughly than other types of commercial buildings.

The energy intensity of office buildings grew significantly between World War II and the 1973 Oil Embargo, for three main reasons: 1) the great popularity of glass facades (mainly single-glazed); 2) very intensive area lighting (up to 6 W/ft^2); 3) very large and inefficient HVAC systems. This trend began to change in 1975 when ASHRAE passed its now-famous voluntary Standard 90-75, which recommended a factor of two reduction in annual resource energy use, down to 250 kBtu/ft^2-yr, as shown in Figure 1. In many new buildings constructed in the late 1970's this was cheaply accomplished by countering the three trends mentioned previously.

Standard 90-75 was so successful that it was voluntarily revised in about 1980. Recommended lighting power was reduced to no more than 2 W/ft^2, and supplemented with task lighting. The point marked "BEPS", at 110 $kBtu/ft^2$-yr, was originally proposed by the Carter Administration as a mandatory Building Energy Performance Standard but was recast as a voluntary guideline by the Reagan Administration. The point marked "LCC" at 71 $kBtu/ft^2$-yr is the estimated Life-Cycle-Cost minimum using 1980 technology, with considerable attention to daylighting and thermal storage. Its first cost is \$1-2/ft^2 (i.e., only a few percent) more than today's typical costs. The buildings need almost no space heat--the 70 $kBtu/ft^2$-yr of resource energy is almost all electricity for lighting, ventilation, and equipment. Also it is reassuring to note (as shown in Fig. 1) that the Swedes are following a similar path, but are a few years ahead of us, and never reached the excesses of our worst buildings. New Swedish office buildings, of which the first of its class was the Farsta Folksam building (plotted at 90 $kBtu/ft^2$-yr), have enough thermal storage to get through a long Stockholm winter with only 6 kWh/ft^2-yr of electricity for routine lighting and equipment, and 20 $kBtu/ft^2$-yr of district heating.

Also on this graph (Fig. 1) we plot (denoted by "X's") the 7 recently-constructed (between 1975 and 1979) office buildings presented at this conference for which we have actual resource energy consumption data. They represent the forefront in energy-efficient commercial buildings and range roughly between 100 and 170 $kBtu/ft^2$-yr in resource energy usage (in agreement with other new office buildings in our data base). These same office buildings are shown as "X's" on Figure 2 where the fuel usage in $kBtu/ft^2$-yr is plotted versus the site electricity usage in kWh/ft^2-yr. We see that 5 out of the 7 buildings are all-electric, a trend followed by many of the new commercial buildings. Points representing the Swedish, French, and U.S. stocks and the ASHRAE standards are shown for comparison in Fig. 2.

In Figure 3 we plot a histogram of the total site energy usage per unit floor area for all of the new energy-efficient commercial buildings presented at the Denver Workshop. The buildings with actual performance data (N = 11) are listed in Table I. They were constructed between 1975 and 1979 and vary in site usage between 20 and 60 kBtu/ft^2-yr, but cluster at the 40-50 range. The buildings with design data only (N = 13) are listed in Table II and display a wide scatter in energy usage with almost one-half of them in the 20-30 kBtu/ft^2-yr range. They are either under construction or have been recently completed and represent newer stock than the set of buildings for which we have metered usage data. More energy-saving design features have been incorporated in the construction of the newer commercial buildings and they are potentially more energy-efficient than the older stock.

Next we list some of the energy-saving characteristics of the new buildings reported at Denver. These features hold true for the majority of the 1975-79 buildings and for almost 100% of the newer 1980-84 buildings.

- Connected lighting loads have been reduced to the range of 1.0 to 1.8 watts/ft^2.

- Daylighting, photocell controls for lighting levels, and supplementary task lighting are commonplace.

- Envelope strategies include extra insulation, moderate window areas, and special treatments (especially shading) for the glazing.

- Variable air volume distribution, heat recovery systems, economizer cycles, natural cooling and ventilation, thermal storage, and energy management control systems are now the "norm" for HVAC systems.

- o Designing the building for the particular site (utilizing and being innovative with whatever is available) is the general practice.

4. COMMERCIAL SECTOR RETROFITS

There is considerable potential for improvement in the energy efficiency of the existing U.S. stock in the commercial sector. The initial retrofit efforts are summarized in the present edition of BECA-C [Ross and Whalen 1982].

The picture pieced together from the BECA-C compilation of "first generation" commercial retrofits is as follows: they are mainly low-investment "proven" retrofits which cost less than $1/ft^2, save approximately 20% in resource energy, and have relatively fast payback times (less than 3 years) and low costs of conserved energy (less than 1981 energy prices). In Figure 4 we see that almost all of the buildings included operations and maintenance (O & M) as part of the retrofit. The second most popular measure was lighting (mainly delamping and replacements of fluorescent tubes with more efficient ones). The energy savings/ft^2-yr vs. pre-retrofit usage/ft^2-yr are displayed in Figure 5. There is a vague general trend toward increased savings with increased energy use. Wide variations in percentage savings are quite evident. Figure 6 shows the distribution of simple payback periods for the subset of the overall compilation which had complete cost data (excluding "failed" retrofits). Almost 90% of the sample achieved payback periods of three years or less. The median value is in the 1 to 2 year range.

The six commercial building retrofits presented at the Denver Workshop are described in Table III. The sample size is too small for any general conclusions to be made. The two retrofits with actual performance data show source energy savings of 36% and 22% respectively and one has a simple payback time of 2.5 years, all consistent with the overall results from the first edition of the BECA-C compilation. The retrofit measures implemented by our small sample include the more popular ones listed in Figure 4 but hint at a possible trend towards more extensive retrofits than simple O & M (operations and maintenance).

5. CONCLUSIONS

It is evident that progress is being made in improving the energy efficiency of buildings in the U.S. New products such as heat mirror windows, high-frequency solid-state ballasts for fluorescent lamps, efficient light bulb replacements, and microcomputer control systems are available in the marketplace. Useful analytical methods and models along with computer simulations have enabled scientists, engineers, and architects to gain an understanding of the energy needed for particular end-uses and to design efficient structures. Techniques such as earth berming, superinsulation, thermal storage, and innovations in HVAC systems and controls have decreased the energy requirements for buildings. Better operation and maintenance procedures have reduced energy consumption. Possible problems associated with "tightening" buildings, such as indoor air quality, are being carefully examined.

Preliminary analyses of actual buildings energy consumption data confirm the progress in energy efficiency. New commercial buildings use less energy than the existing stock. Time trends indicate a steady improvement in the energy efficiency of new construction. Many low-energy buildings are being constructed for no extra cost. Retrofits in the commercial sector have shown a wide range in energy savings and costs but most have been cost-effective--although modest and "conventional" investments.

The data compiled from the commercial buildings presented at the Denver Workshop are consistent with the results from our overall data base. Many new office buildings and new schools, at the forefront of energy efficiency and hence much better than average new stock, are presently achieving energy consumption levels in the range of 35-60 kBtu/ft^2-yr (site) and 100-170 kBtu/ft^2-yr (source). Many new office buildings under construction have design energy consumption values in the general range of 25-60 kBtu/ft^2-yr (site).

As a barrier to accurate analysis of buildings energy usage, we note the relative paucity of good-quality building performance and economic data in general. Even for the Denver Workshop buildings, the details for most buildings were sparse. Out of 31 reported buildings, only 13 had metered consumption data (about 10 of the buildings are either under construction or have been in operation for less than a year); only a few had good cost data or had economic analyses; most dealt with only site energy units (as opposed to source units); and almost none listed peak electricity demand levels. In an attempt to gain comprehensive details (such as discussed above) about a group of buildings that we consider to be among the most energy-efficient in the country, we sent out rather lengthy follow-up questionnaire forms to the Denver Workshop participants. After several months, we have yet to receive the first reply. We encourage our Denver Workshop colleagues and others working in the buildings sector to gather extensive performance and economic data and to share it with us so that we can develop an accurate and useful commercial buildings data base.

Collection and analysis of metered energy consumption data for buildings of all types in climate zones throughout the country, for multiple years, are needed to accurately evaluate what progress is being made in the energy efficiency of buildings. Better cost data would improve the economic analysis. We at LBL solicit your assistance.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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Solar Energy Research Institute (1981), A New Prosperity: Building a Sustainable Energy Future, Brick House Press, Andover, MA.

Ross, Howard, and Whalen, Sue (1982) "Building Energy Use Compilation and Analysis (BECA) Part C: Conservation Progress in Retrofitted Commercial Buildings," Lawrence Berkeley Laboratory Report LBL-14827.

Table I. Denver Workshop: New Commercial Buildings with Actual Performance Data

Building Type	Location	Floor Area (10^3 ft^2)	Construction Completion Date	Site Fuel Usage ($kBtu/ft^2$-yr)	Site Elec. Usage (kWh/ft^2-yr)	Total Site Energy Usage ($kBtu/ft^2$-yr)	Total Source Energy Usage ($kBtu/ft^2$-yr)
Office	Idaho	284	1979	0	11.0	37.6	126.7
Courthouse/ Office	Alaska	631	1979	NA	NA	40.2	NA
Retail	Indiana	7.6	1979	NA	NA	42.5	NA
Office	Texas	14.6	1978	4.3	10.4	39.7	124.7
Office	Colorado	9	1977	0	8.4	28.8	97.2
Office	Canada	1300	1975	0	15.4	52.5	176.9
Office	Wisconsin	89.6	1979	0	11.9	40.6	136.7
School	Wisconsin	35.8	1979	28.3	3.8	41.5	72.5
School	Wisconsin	46.9	1979	0	15.2	51.7	174.3
Office	Wisconsin	101.2	1979	0	13.7	46.7	157.3
Office	California	135	1979	14.7	7.4	40.0	100.0

Table II. Denver Workshop: New Commercial Buildings with Design Data Only

Building Type	Location	Floor Area (10^3 ft^2)	Construction Completion Date	Predicted Site Energy Usage ($kBtu/ft^2$-yr)
Office	New York	200	1982	27
Office	New Jersey	260	1983	25
Office	Ohio	430	1984	47
Office	Hawaii	177	1983	149
Office	Texas	800	1981	33
Office	California	31.6	1982	23
Office	California	155	1982	78
Office	Ohio	85	1980	72
Office	New Jersey	220	1984	28
Office/ Retail	Indiana	1241	1982	29
Office	New York	925	1984	43
Science Museum	Virginia	21+	NA	33
Bus Maint. Facility	Colorado	351	1980	20
Maint. Garage/ Office	North Carolina	16.2	1980	NA

Table III. Denver Workshop: Commercial Building Retrofits

Building Type	Location	Floor Area (10^3 ft^2)	Year of Retrofit	Retrofit Measure(s)	ENERGY USAGE Before Retrofit ($kBtu/ft^2$-yr)	ENERGY USAGE After Retrofit ($kBtu/ft^2$-yr)	Savings	Simple Payback Time (yr)
Office	Pennsylvania	52	Ongoing	HVAC, O&M Lighting Envelope	194 (site)	NA	65% (predicted)	NA
Office/ Museum	New Mexico	29.7	1982	Atrium (passive solar)	NA	96.5(site) (predicted)	NA	NA
Office/ Switching Facility	Wisconsin	39.0	1979	HVAC, O&M	226.3(site) 518.4(source)	124.8(site) 332.5(source)	101.5(site) (45%) 185.9(source) (36%)	2.5
Map Producing Facility	Missouri	470	1979	HVAC, EMCS	387.5(site) 800.8(source)	249.9(site) 622.4(source)	137.6(site) (36%) 178.4(source) (22%)	NA
Industrial	Washington	209	1982	Lighting	12.1(site) LIGHTING ONLY	7.5(site)	4.6(site) (38%)	4.8
Office/ Bank	Massachusetts	837	1982	Lighting	29.9(site) LIGHTING ONLY	NA	NA	NA

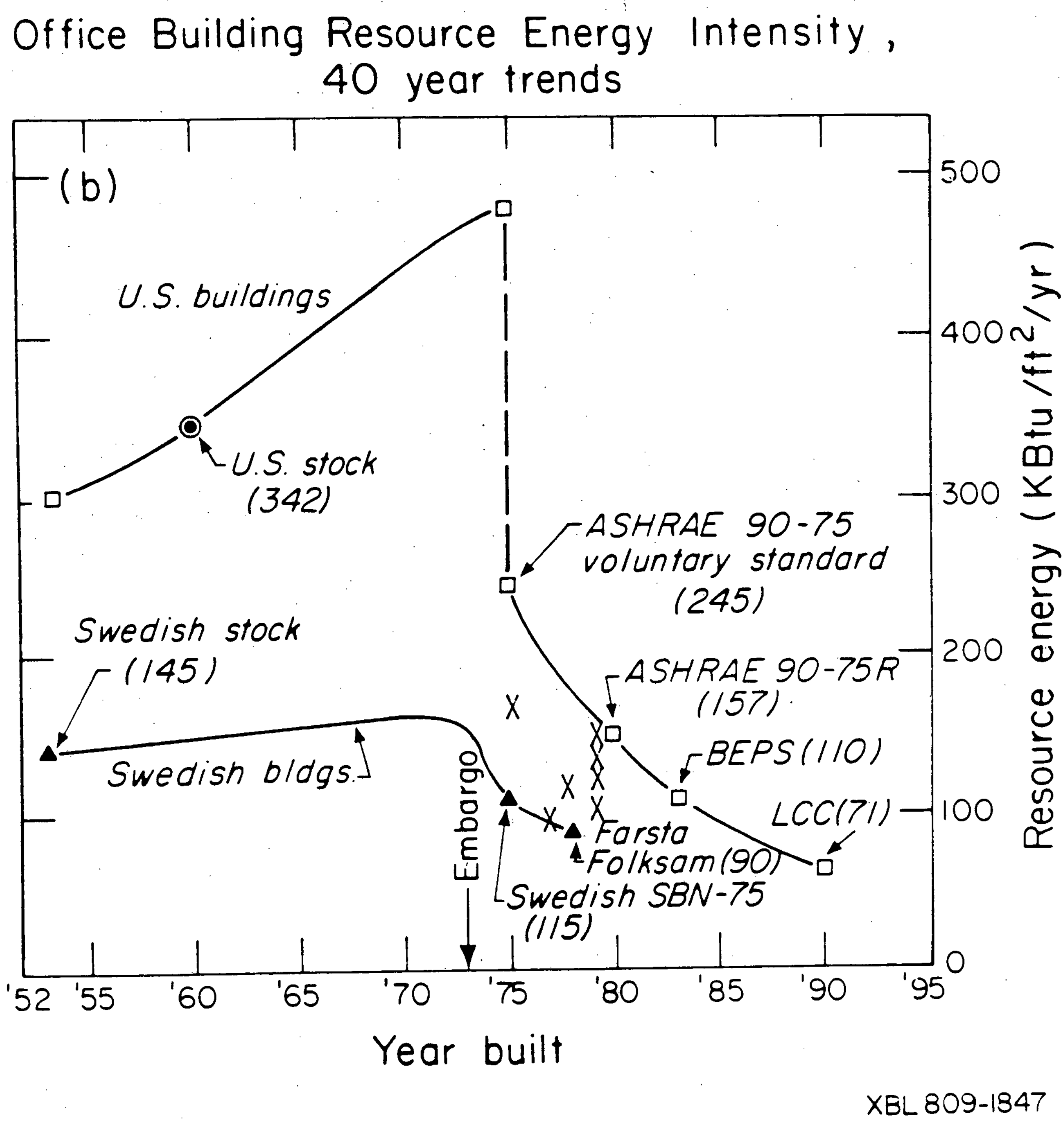

Figure 1. Forty-year trend in annual energy use per unit floor area of new U.S. and Swedish office buildings. Seven recent energy-efficient office buildings (reported at the Denver Workshop) are represented by "X's". Electricity is counted in resource energy units of 11,500 Btu per kWh.

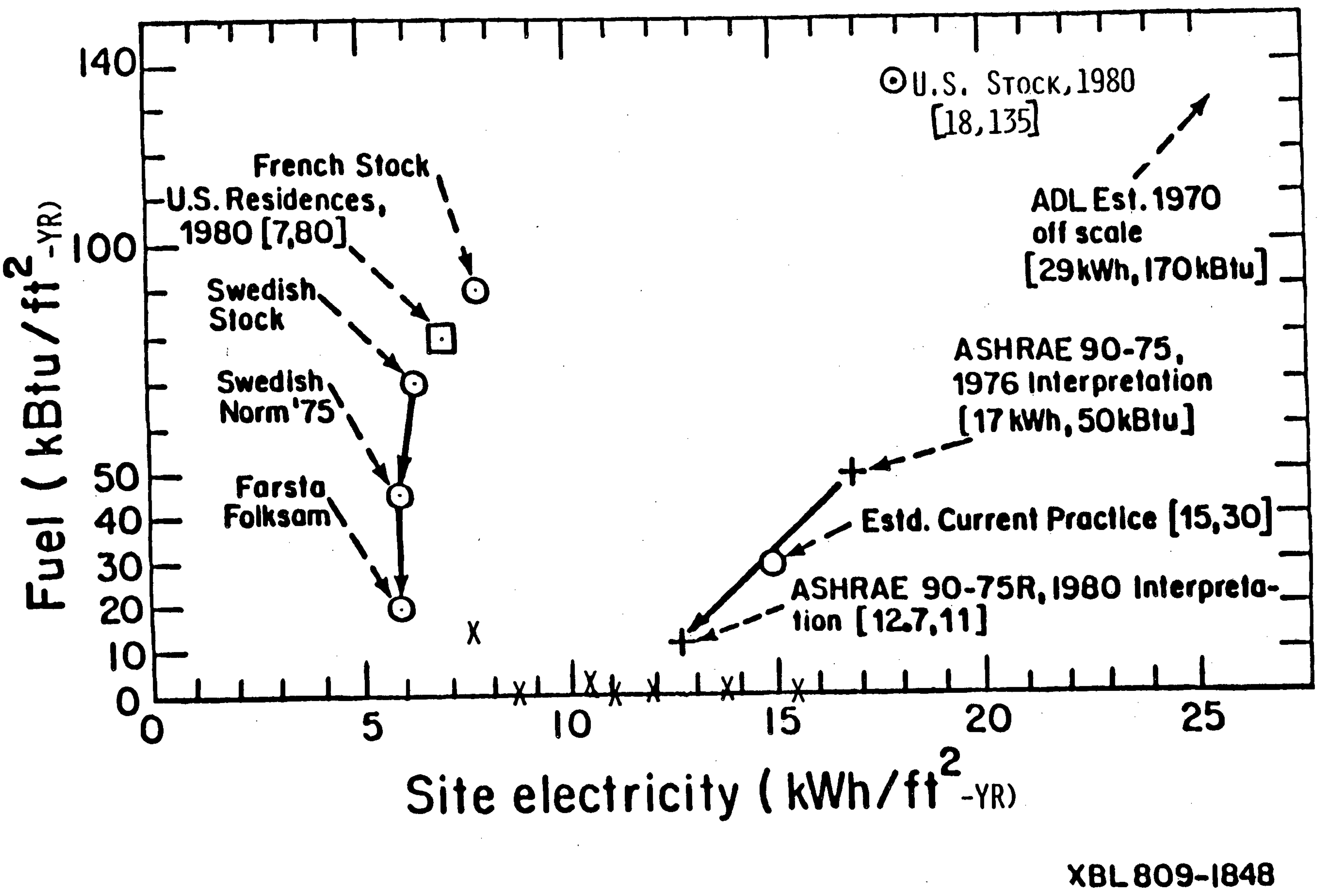

Figure 2. Energy use of existing and new U.S. office buildings. Progress in Swedish building efficiency is shown for comparison. Seven recent energy-efficient office buildings (presented at the Denver Workshop) are represented by "X's".

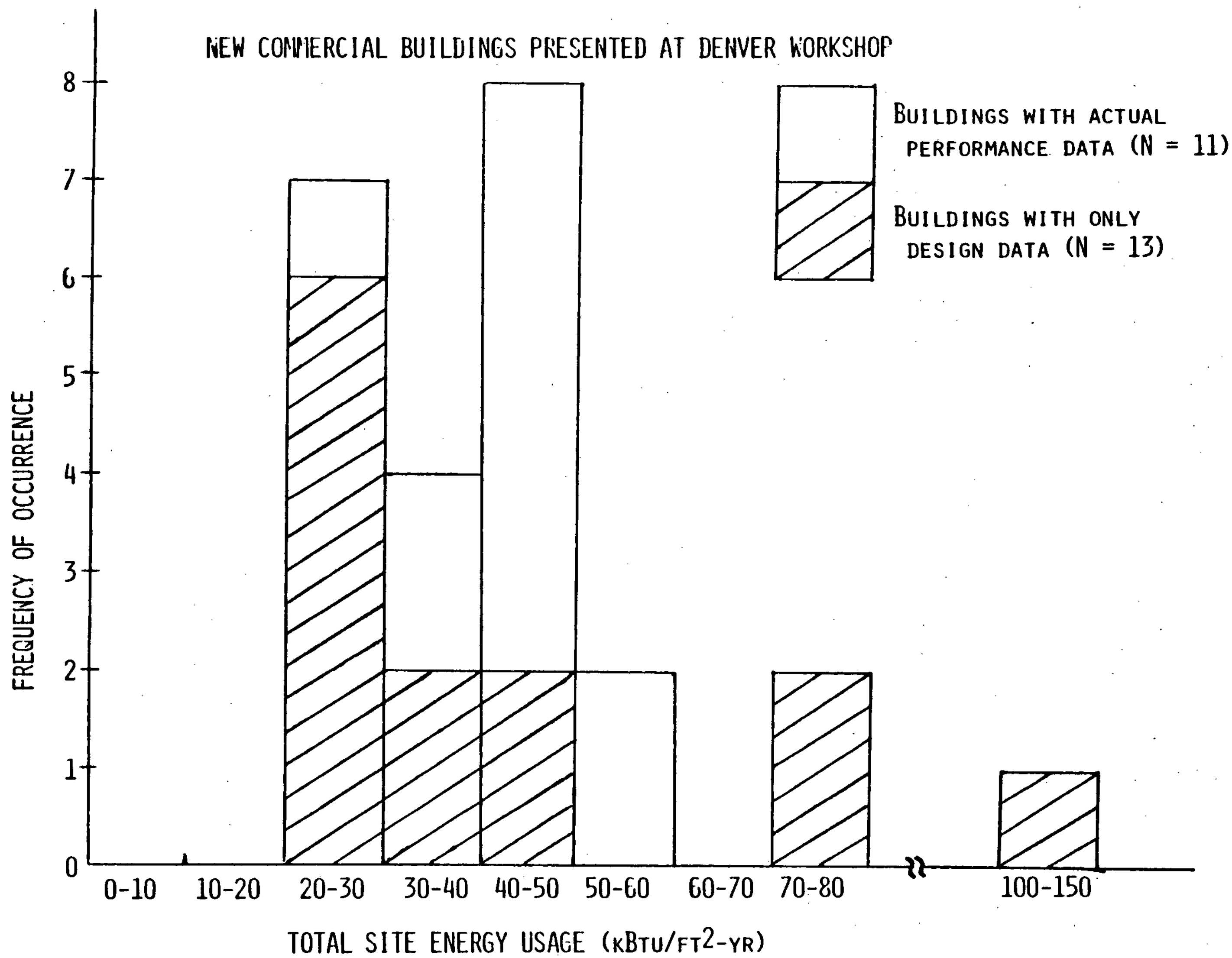

Figure 3. Histogram of the distribution of total site energy usage for the new commercial buildings presented at the Denver Workshop. The buildings are separated into two groups: those with performance data and those with design data.

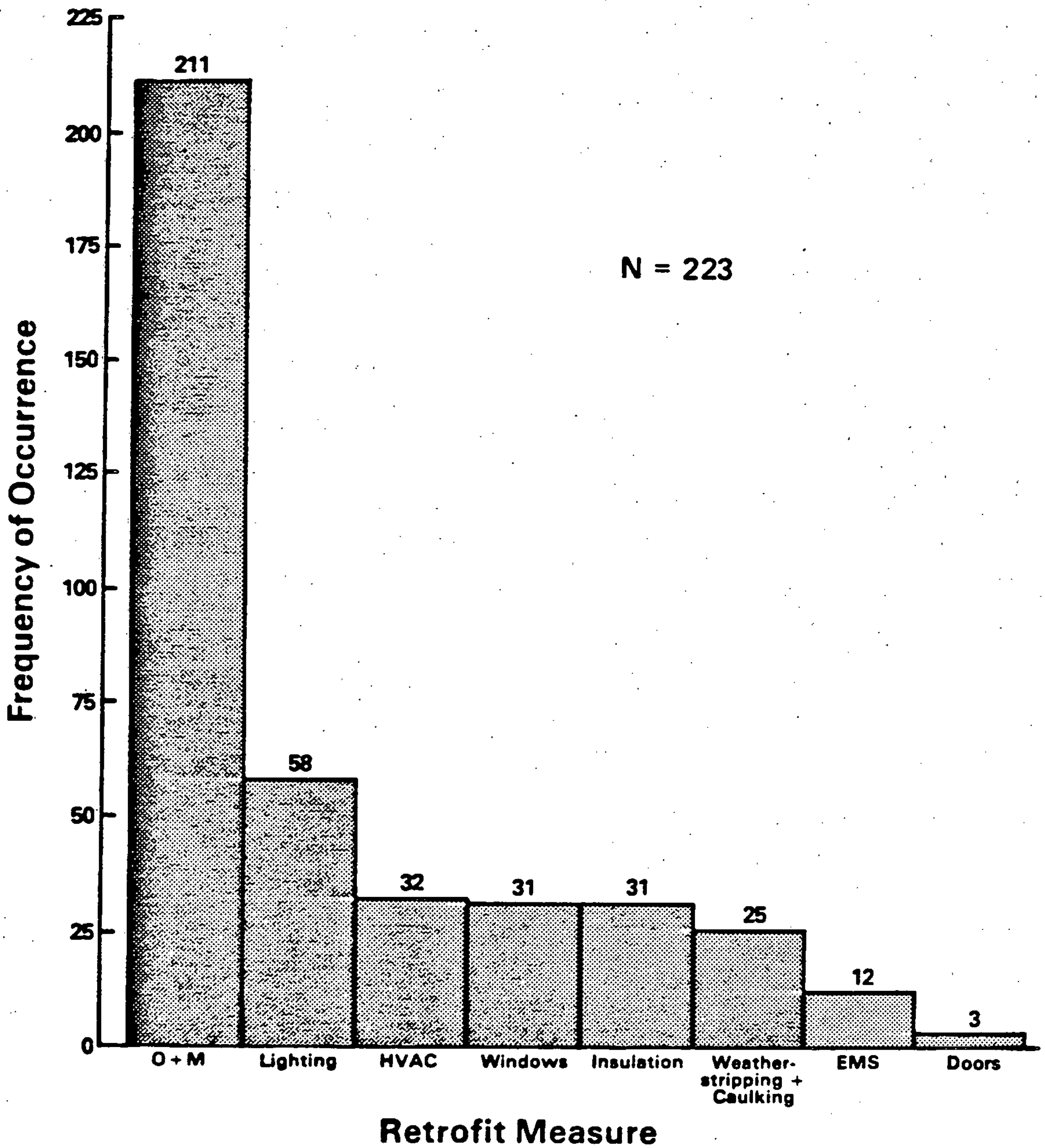

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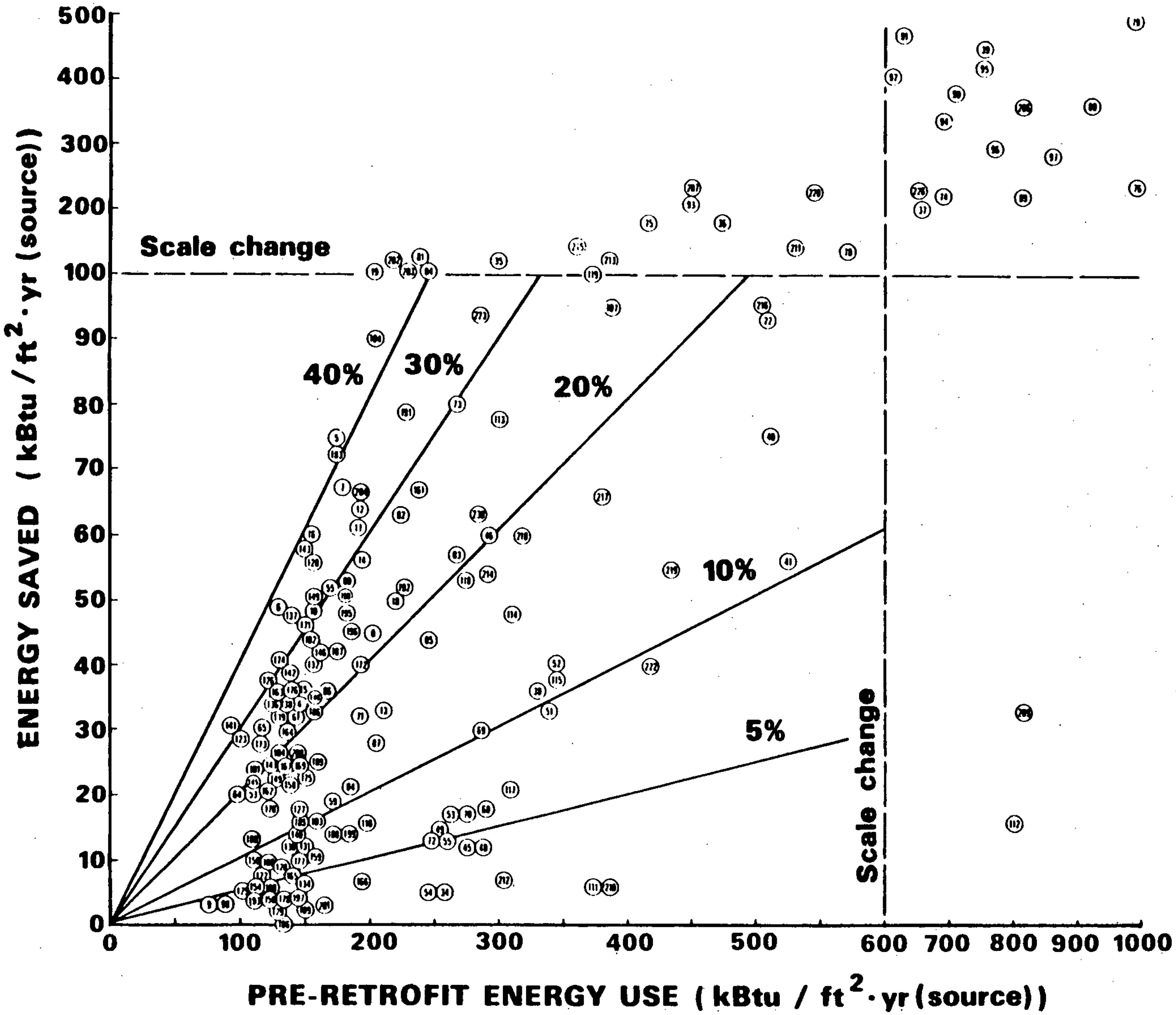
Figure 4. Histogram of installed measures for commercial building retrofits contained in the BECA-C data base.



XBL 826-792

Figure 5. Energy savings vs. Pre-retrofit energy use for commercial building retrofits contained in the BECA-C data base. Beware the scale change on the figure. Reference lines corresponding to 5% through 40% savings are drawn.

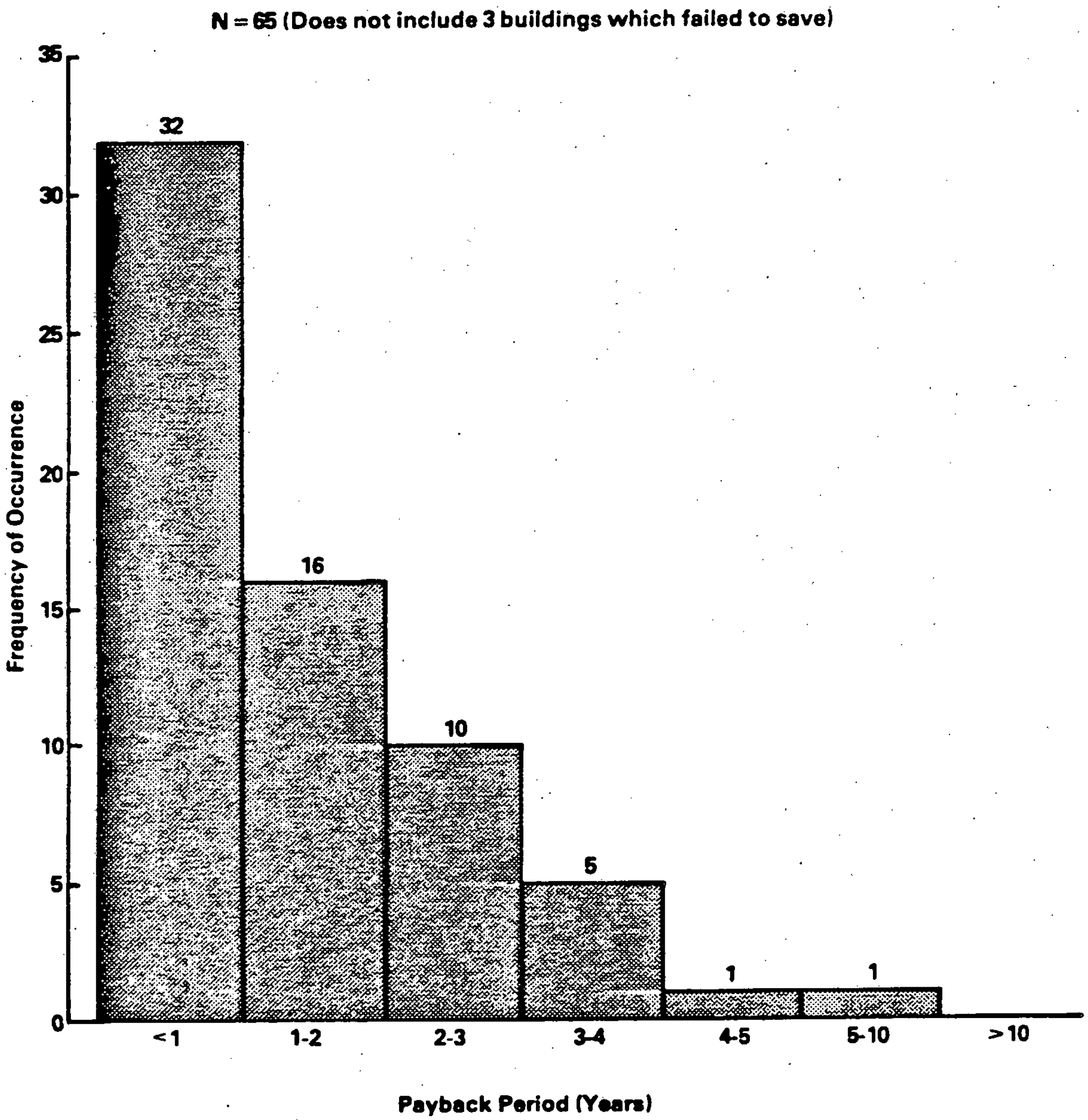


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Figure 6. Histogram of simple payback periods for the subset of commercial building retrofits from BECA-C which have complete cost data.

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